Norwegian Hydrographic Service

and

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APPENDIX B

Technical Specifications

MAREANO Programme

11.12.2017

Some changes are made in this updated MAREANO specification dated 11 December 2017. The changes are basically related to echosounder specifications, sound velocity and absorption coefficient profiles, backscatter and sub bottom profiler requirements. Some additional minor changes are also made.

Technical Specifications

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1 Overview

This specification gives the requirements for data to be used in the MAREANO programme. In addition to product specifications, some equipment and procedure requirements are also presented.

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2 Terms and Definitions

Calibration

Calibrations comprise both the determination of corrections and the use of these corrections.

Complete Dataset

A complete dataset consists of hydrographic data satisfying data coverage requirements in terms of total area, survey area limits, sounding density and restrictions on data gaps.

Field Verification

A field verification of the survey spread calibration is based on analysing overlapping hydrographic data collected in a small area with suitable seabed characteristics. The survey pattern is selected in a way that any calibration error is as visible as possible.

Hydrographic Data

All data gathered during the survey and all the related metadata required for seabed mapping.

Mobilisation and Demobilisation

This includes all activity related to preparation and survey spread setup and dismounting.

The mobilisation is not considered completed until Client has approved the documentation of all calibration and verification activity as described in Section 8.1.

Survey area limit

A closed polygon that surround all measured and QC data in a project. Under certain instances, several limits may be needed.

Survey spread

This includes the survey vessel itself and all the equipment required to perform the survey.

Survey vessel reference frame

This is an orthogonal coordinate system with a fixed position and orientation relative to the survey vessel hull.

Verification

Verification determines if a system or a sensor operates within specifications.

Unambiguous dataset

This indicates that every position on the seabed is assigned only one unique depth.

XYZ-data

The term XYZ- data is used to describe georeferenced individual soundings from the MBES.

3 Abbreviations

EUREF89	Is the same as the European Terrestrial Reference Frame 1989 (ETRF89)
GNSS	Global Navigation Satellite Systems
IERS	International Earth rotation and Reference system Service
IGS	International GNSS Service
IHO	International Hydrographic Organisation
ITRF	International Terrestrial Reference Frame
MBES	Multibeam Echosounder
MSL	Mean Sea Level
MVP	Moving Vessel Profiler (used for "continuous" sound velocity or CTD observations)
NGU	The Geological Survey of Norway
NHS	The Norwegian Hydrographic Service
OM	Operation Manual
QC	Quality Control
SVP	Sound Velocity Profile
THU	Total Horizontal Uncertainty (defined in IHO-S44)
TVU	Total Vertical Uncertainty (defined in IHO-S44)

4 Informal description of the data product

The Contractor shall deliver complete and unambiguous hydrographic data having the desired accuracy, collected with multibeam echo sounder (MBES) at its highest resolution mode.

In addition to the general seabed topography, all seabed features (like iceberg scour marks, coral reefs, pockmarks, sand waves and boulders, etc.) are very important to the MAREANO programme. Both the survey and the processing shall be carefully done to preserve all the seabed feature information and removing all the faulty soundings. Seabed features shall not be camouflaged by artefacts and artefacts must not appear as seabed features. No smoothing of the XYZ data shall be applied. Backscatter data are equally important as bathymetry data for the MAREANO programme. The multibeam backscatter data shall provide a representative view of natural variations in seabed acoustic reflectivity within the survey area, such that they are suitable for geological mapping.

5 Equipment Requirements

Positioning

The GNSS antenna positioning uncertainty shall be within 0.3m (95%) for the horizontal component and within 0.1 m (95%) for the vertical component. Post processing of positioning is accepted. The positioning shall be based on a high- quality dual frequency GNSS receiver and a high- quality calibrated GNSS antenna type. All the raw data shall be stored for post processing.

Multibeam Echosounder (MBES)

<table>
<tr><td>Maximum across track beam width for the actual applied sonar frequency in a direction perpendicular to the transducer surface</td><td>Depth 0-1000 m: 1.4°
Deeper areas: 2.4°</td></tr>
<tr><td>Maximum along track beam width for the actual applied sonar frequency</td><td>Depth 0-1000 m: 0.7°
Deeper areas: 1.2°</td></tr>
<tr><td colspan="2">The echosounder shall have a depth range well suited for the survey area. The echosounder with the highest suitable frequency will generally be preferred.</td></tr>
<tr><td colspan="2">The MBES shall fulfil the accuracy requirements given in chapter 7</td></tr>
<tr><td colspan="2">Both CW and FM systems are accepted provided that both the depth accuracy and the backscatter data quality are within specifications.
Range resolution preferences:
<table>
<tr><th>Depth range</th><th>Maximum value for range resolution δR</th></tr>
<tr><td>0-200 m</td><td>0.2 m</td></tr>
<tr><td>200-400 m</td><td>0.5 m</td></tr>
<tr><td>400-700 m</td><td>1.5 m</td></tr>
<tr><td>700-1500 m</td><td>3.0 m</td></tr>
<tr><td>1500-4000 m</td><td>4.0 m</td></tr>
<tr><td>4000-12000 m</td><td>8.0 m</td></tr>
</table>
CW mode: $\delta R = \frac{cT_p}{2}$
FM mode: $\delta R = \frac{c}{2B}$
Where:
T_p = pulse length,
c = sound velocity and
B = FM bandwidth.</td></tr>
<tr><td colspan="2">Phase detection shall be utilized (except for near nadir beams)</td></tr>
<tr><td colspan="2">Sound velocity at transducer shall continuously be observed and input to the MBES in real time</td></tr>
<tr><td colspan="2">Online input of sound velocity profiles to the MBES. The profiles shall be transferred to the MBES and utilized in near real time.</td></tr>
<tr><td colspan="2">Roll, pitch and yaw beam compensation (all soundings shall be corrected for vessel movements)</td></tr>
<tr><td colspan="2">Equidistant sounding pattern shall be utilized</td></tr>
<tr><td colspan="2">Realtime roll and pitch steering shall be utilized to ensure an even sounding distribution</td></tr>
<tr><td colspan="2">Beam focusing shall be utilized both on transmit and receive</td></tr>
<tr><td colspan="2">Seabed reflectivity (backscatter) shall be collected</td></tr>
<tr><td colspan="2">Online input of absorption coefficient profiles to the MBES. The profiles shall be transferred to the MBES and utilized in near real time.</td></tr>
<tr><td colspan="2">Water column data shall be collected</td></tr>
</table>

Sediment echosounder

Minimum recording window below seafloor	200 ms TWT
Maximum frequency (shipborne system)	20 kHz
Minimum frequency (shipborne system)	2.5 kHz
Delay time change	Manual
Roll, pitch and yaw compensation/recording	All soundings shall be corrected for vessel motions

Attitude and heading sensor

The sensor requirements are:

Heading (GNSS based)	0.05° RMS
Roll and Pitch	0.02° RMS
Heave	0.05 m or 5% of amplitude
Output rate	Min. 100 Hz

The Heading shall be GNSS-based or GNSS-aided. Heading purely based on inertial sensors is not accepted. Post processed heave is accepted.

Sound Velocity and Absorption Coefficient profiles

The time between measured profiles shall not exceed two hours. Profiles to the full survey depth shall be made at least once every 6 hours. The rest of the profiles may be made to shallower depths only where the deeper layers show insignificant sound velocity variations. The profiles shall have a good spatial, as well as temporal coverage of the oceanographic conditions. There must be sufficient deep profiles in deeper areas to provide good corrections for these areas and deep profiles shall be used for shallow profile extension. All profiles must be visually inspected before they are used.

Action must be taken to identify sound velocity challenges specific to the area and to acquire enough SVP profiles to sufficiently represent the spatio-temporal variations.

The equipment shall preferably be a CTD sensor but a carbon fibre based "sing-around" sound velocity + temperature sensor will also be accepted. The sensor requirements are:

Temperature	0.01°C RMS
Sound velocity	0.05 m/s RMS
Depth range, full scale	0.05% RMS

Profiles of absorption coefficient shall be calculated from the measured CTD profiles. E.g. the input of a single salinity value is not accepted. The profiles shall be calculated and applied without significant delay, and logging of a new line shall be started. Manual adjustments during logging shall not be made.

Formulas for calculations from measured CTD:

The formula from [*Chen and Millero*] or [*Del Grosso*] shall be used for calculation of sound speed.

Formula from [*Francois and Garrison*] shall be used for absorption coefficient calculation.

Sound velocity at transducer head

The sound velocity shall continuously be measured close to the sonar head(s) and automatically be applied by the MBES. This sensor shall utilize "sing around" sound velocity observations over a carbon fibre distance base. Accuracy requirements are the same as for the sound velocity profiles.

6 Reference Systems

Horizontal

The horizontal reference system for all the data shall be EUREF89. ITRF positions must be transformed to EUREF89. The transformation formulas shall be approved by the Client.

Vertical

All depths shall be given as ellipsoidal depths in the EUREF89 datum.

Timing

All registrations of time shall be given in Co-ordinated Universal Time (UTC).

7 Data Quality Requirements

7.1 *Resolution*

The beam angle from nadir shall not exceed 60°. For deep areas where the echosounder range is the limiting parameter, the swath width shall be reduced to obtain good data on the outer beams. This gives the densest possible coverage within the maximum available swath width.

The sounding distance (both along track and across track) shall not exceed **2*depth*tan(60°)/399.**

The along track sounding distance shall not significantly exceed the across track sounding distance.

7.2 *Accuracy requirements*

General information about the requirements:

1. The requirements only apply for ***accepted*** data.
2. The requirements apply for ***all*** the accepted data (***not*** 95%)
3. Every accepted sounding shall fulfil ***all*** the specified requirements.
4. Accuracy limits scale with depth. The depth used in the formulas below, is the vertical distance between the mean sea level and the seabed.

7.2.1 Horizontal accuracy requirement

The horizontal position of the soundings on the seabed shall be within **±(0.5m + 0.016*depth)** from the correct value.

7.2.2 Overall vertical accuracy requirement

All accepted soundings shall be within the vertical distance of **±(0.25m + 0.004*depth)** from the correct value.

7.2.3 Vertical precision (consistency) requirement

The vertical precision (as defined in section 7.3.2~~7.3.2~~) shall be within **0.2m + 0.004*depth**.
The vertical precision is a point-to-point total depth difference and ***not*** a ± value.

7.3 *Accuracy verification*

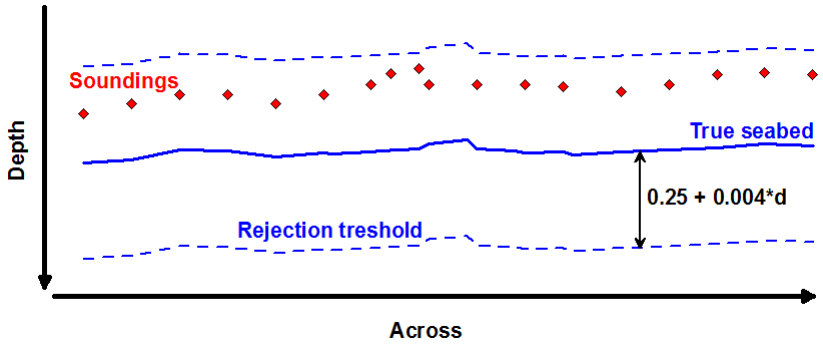
The accuracy of the soundings will be checked in two steps

1. Verification area survey
2. Main survey consistency check

7.3.1 Verification area survey

Minimum one verification area shall be surveyed prior to the main survey. This area shall be an existing well-surveyed area with an already established reference surface.

Data from the verification survey shall be processed, and the accepted soundings will be compared to the existing reference surface.



The verification survey is used to check both the overall vertical accuracy (section 7.2.2) and the horizontal accuracy (section 7.2.1). Data acquisition in the verification area shall include backscatter, water column data and data from any other instrument which will be operated during the course of the survey. All data from the verification survey shall be delivered prior to the start of the main survey. These data will be checked as early as possible, preferably before the main survey starts.

7.3.2 Main survey consistency check

The internal consistency of the main survey is checked by comparing overlapping lines and neighbouring soundings. It is a measure of how well the overlapping lines and neighbouring soundings fit together. In this specification the vertical precision is defined as the vertical distance between neighbouring soundings. Physical terrain variations over the horizontal distance between the soundings must be considered and should ideally not be a part of this difference. This fact gives room for some subjective judgements regarding the measured depth differences.

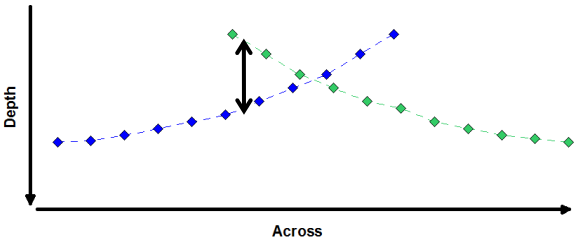


Figure 1 The overlap between two survey lines shows a depth difference between the two lines. In this example the vertical precision is the same as the difference in depth level between the lines.

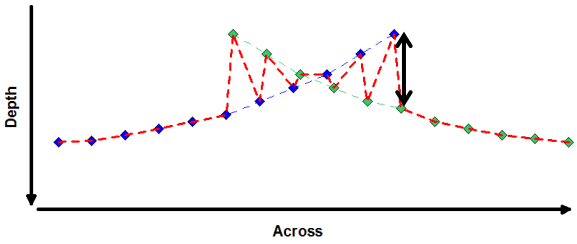


Figure 2 The tools used by NHS determines the vertical precision from the point-to-point variations (red line). Some allowance for real terrain variations must be added.

The overlapping areas between lines and neighbouring data will be used to check the vertical precision (section 7.2.3).

Seabed features in overlapping areas will be used to check the horizontal accuracy (section 7.2.1).

7.4 *THU and TVU*

The 95% THU and TVU values as defined by IHO shall be calculated and reported for all soundings. These values shall be calculated from the best available knowledge about the survey system. No parameters shall be adjusted to fit the values to the specified requirements. The reported THU and TVU values will not be used for data rejection.

7.5 *Timing*

All data are to be time-stamped to **UTC** within **1ms (95%)**.

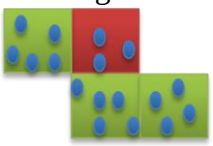
The Contractor shall read and timestamp all sensor data, and the Contractor is urged to document the timestamp uncertainty. Preferably all survey data (observations) shall be time stamped at source.

7.6 *Data gaps*

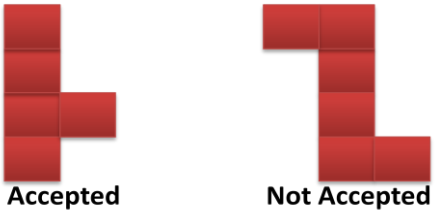
Data gaps are caused by missing soundings or by soundings rejected in the data processing. The accepted bathymetry data shall be checked for data gaps by defining a data gap grid (DGG). The DGG grid size is 2.5 times the nominal sounding distance.

Depth [m] Relative MSL	Nominal abeam sounding distance[m]	DGG grid size
3-10	0,1	0,5
10-20	0,2	0,7
20-40	0,4	1,0
40-70	0,6	1,5
70-100	0,9	2,5
100-200	1,7	4,5
200-300	2,6	6,5
300-400	3,5	8.5
400-500	4,3	11,0
500-600	5,2	13,0
600-700	6,1	15.0
700-800	7,0	17.0
800-900	7,8	19,5
900-1000	8,7	21,5
M	M	M
3300-3400	29,5	73,5
3400-3500	30,4	76,0

A DGG cell with less than **4** accepted soundings is defined as a gap



More than five adjacent DGG gap-cells are not accepted



A DGG cell with less than **4** accepted soundings is defined as a gap.

More than five adjacent (i.e. cells sharing one side) DGG gap-cells are not accepted, unless the area is without significant topographical details. In areas with no significant topographical details, a maximum of two subsequently missing pings are accepted. Inter-ping gaps due to yaw compensation, are also accepted in such areas. The total number of gaps shall, however, not exceed 0.1% of the DGG cells.

7.7 *Backscatter data*

High resolution, georeferenced backscatter data shall be collected to provide information on seabed acoustic reflectivity, which is required by MAREANO for geological mapping purposes. Note that that backscatter data quality is often independent of the bathymetry data quality and must be checked regularly to ensure that it provides a representative view of the natural variations in the acoustic reflectivity of the seabed. Data are considered unusable where they are dominated by noise or other artefacts. Unusable backscatter data is not acceptable for MAREANO, just as data gaps are not acceptable for bathymetry data (section 7.6).

The Contractor shall take all necessary measures to obtain the best possible backscatter data quality and shall be familiar with the guidelines and recommendations provided by the GeoHab backscatter working group (Lurton and Lamarche, 2015), in particular Chapter 5 Acquisition: best practice guide. Further to this, the Contractor shall follow the guidelines below:

- For multi-sector MBES the echosounder must be sector calibrated prior to mobilisation and the MBES data shall be backscatter normalised upon delivery.

- Good quality backscatter data shall be acquired for the entire survey area. Missing data, or data of unusable quality shall not exceed 1% of the total area of each survey block. Backscatter data are generally more sensitive to bad weather than bathymetry data. Survey speed and/or line direction should be adapted to obtain the best possible data and the survey suspended if many missing or bad pings are visible in the backscatter data.

- The backscatter data quality shall be monitored continuously during data acquisition, and backscatter mosaics of each survey block shall be routinely produced onboard for QC purposes (5 m resolution or finer in depths shallower than 500 m; 10 m resolution or finer in depths of 500-1200 m). No cosmetic levelling of dB values shall be applied to these mosaics. The contractor shall endeavour to avoid multibeam receiver acoustic saturation of the backscatter data. Any depth or noise filters applied should not have a detrimental effect on the backscatter data quality, nor cause irretrievable loss of data.

- The Contractor shall ensure that systematic variations to backscatter intensity are kept to a minimum and shall avoid the use of automatic acquisition settings as these cause problems for backscatter data processing and interpretation. This includes application of valid absorption coefficients at all times. All real-time acquisition parameters required to conduct post processing shall be included with the digital logged data. It is important that changes in settings for gain, pulse length, frequency, or any other system changes are minimised.

- Where changes to acquisition settings are unavoidable across the survey area due to bathymetric mapping requirements, the survey should be split into contiguous sub-areas (blocks) with consistent settings. These considerations should be taken into account at the survey planning stage (see section 8.4). Minor adjustments may be accommodated by starting logging of a new line any time changes to acquisition settings are made.

- If more than one MBES and/or survey vessel is used within a survey block then at least one line with 100% overlap should be logged, where acquisition is conducted in the same direction to provide a reference line for backscatter interpretation.

7.8 *Sub-bottom profiler data*

Sub-bottom profiler data are essential for mapping bottom types, sedimentary environments and processes on the seabed and below the seabed. Names commonly used for sub-bottom profiler are chirp, pinger, sediment echosounder and high resolution seismic. Sub-bottom profiler data should be collected during the multibeam echosounder mapping cruises.

7.8.1 Requirements for sub-bottom profiler data collection

- Sub-bottom profiling should start (line 1) along one of the boundaries of the area to be mapped.
- Internal distance between sub-bottom profiler lines should not exceed 10 km.
- After this, if more than 5 km remains to the other boundary of the mapping area, a last line should be run along that boundary.
- Straight lines are preferred, but curved lines are accepted if this is necessary to optimize acquisition of bathymetric data.
- The ping rate should be as high as possible, but the recording window below the seafloor should not be less than 0.2 seconds two-way time (TWT). Maximum ping intervals:
    - 0.5 second for water depths shallower than 500 m
    - 1 second for water depths of 500 m and deeper.
- Vertical data resolution should be at least 10 cm for 0-50 m, 20 cm for 50-100 m, 30 cm for 100-500 m, 40 cm for 500-1000 m, 50 cm for 1000-1500 m, and 100 cm for deeper waters.

8 Survey control

The Contractor shall document that all requirements given in this specification have been met. The Contractor shall continuously carry out Quality Control during data collection and processing. The Client shall have access to these procedures.

Any modification of the survey spread shall be documented and reported to the Client.

New equipment shall have the same or better quality as replaced equipment. Introduction of new vessels during the project may be accepted. This will, however, require a full documentation of the equipment and the vessel. The vessel survey report must be accepted by the Client before the new vessel is put into use.

8.1 *Calibration and verification*

The calibration and verification delivery (reports and data files) shall contain all the required information for a third party to verify the results. The uncertainty of the calibration and verification results shall be documented.

The Contractor is responsible for maintaining and documenting the total system performance during the survey. This shall be obtained by calibration and verification.

A verification of all determined calibration parameters is required before the parameters are put into use. This shall be part of the calibration and verification procedure.

Calibration of all equipment in the survey spread

The Contractor shall conduct a calibration of the total survey spread.

The Calibrations shall include but not be limited to:

- *Post-installation calibration*:

  Initial determination of system parameters (e.g. position and orientation of new sensors relative to the Body reference frame)

- *Scheduled calibrations*:

  This comprises both laboratory calibration of instruments according to service interval requirements, and onboard calibration of composite systems

- *Calibration after incidents or after equipment configuration changes*:

  This comprises the calibration of all equipment affected by an incident, as well as calibration after remounting or replacement of essential parts of a system.

8.1.1 Survey vessel reference frame

A reference frame shall be defined for the survey vessel.

A sufficient number of permanently marked points shall be established at suitable locations on the vessel. All points intended for GNSS antenna mounting (e.g. marked by a drilled hole for the antenna attachment bolt) shall be surveyed (it is not sufficient to only survey the antenna itself). Surface vessels shall additionally have a minimum of 4 dedicated GNSS antenna mounts permanently marked in suitable locations for attitude sensor calibration.

Every sensor outputting data sensitive to sensor position or sensor installation angles shall have these values determined in the survey vessel reference frame.

Sensor positions as well as sensor installation angles shall (as a minimum) be determined to the accuracy level specified in the equipment installation manual. The position and installation angle accuracy requirements for every system component must be carefully judged, so that the accuracy of the final product is kept within the specified range.

The uncertainty of all surveyed reference points on the vessel must be sufficient to satisfy the accuracy requirement related to the use of the points (i.e. often related to sensor calibration requirements).

The installation survey report shall contain a full description of the survey and a clear presentation of the results. The procedure for the determination of sensor position and installation angles, as well as the uncertainty of the determined values, shall be well documented.

The installation survey delivery shall include the report and the digital observation files. This delivery shall contain all the required information for a third party to verify the results. An example of such a report can be found in “Info_B_alignment_report.pdf”.

8.1.2 Sensor Alignment

Multibeam Echosounder

The MBES transducer installation angles shall be determined by a land-survey operation to obtain a sufficient connection to the survey vessel reference frame.

Attitude and Heading sensors

Attitude sensors shall be mounted on a rigid, machined surface with steering pins to ensure repeatable precision mounting.

The determination of vessel motion sensor and heading sensor installation angles shall be by use of at least four (preferably more) GNSS antennas, to obtain a time series of the "true" orientation of the survey vessel. During calibration, the vessel shall manoeuvre to obtain realistic attitude sensor behaviour. Installation angles are determined from the difference between the GNSS derived attitude values and the attitude sensor readings. Alternative methods will be accepted if they are documented to give better results.

Positioning sensor

GNSS antenna calibration values from the IGS shall be utilized.

Examples of sensor alignment are given in "Info_B_alignment_report.pdf".

8.1.3 Sensor Calibration

All equipment requiring regular calibrations against standards shall hold a valid calibration certificate from a certified institution. The equipment shall be maintained and handled according to manufacturer's recommendations to make it plausible that the equipment is kept within its accuracy specifications between calibrations.

The Contractor shall keep a historical record of all calibration and verification results for all equipment at the serial number level.

8.2 *Field verification*

The continued validity of the survey spread must be confirmed at relevant intervals during each survey season. Verification schedules shall be presented as a part of the tender. A new Field Verification is required after any modification or reconfiguration of the survey spread.

If the verification determines discrepancies of the installation parameters, additional calibration of the system is required.

As part of the survey mobilisation, the Contractor shall perform a Field Verification to document that the complete survey spread with all equipment systems operates within specifications. This test shall be performed in an area specified by Client.

8.3 *Crosslines and line overlap*

Survey line overlap

There shall be at least 10% overlap between survey lines (a new line shall cover 10% of the preceding line).

Crosslines

There shall be at least one crossline for every sub-survey area. If the sub- survey area size exceeds 500 km^2, there shall be one crossline per 500 km^2. Crosslines may be planned in connection with crew change or infill lines. The crosslines may be split into several parts. Crossline (or crossline segments) shall cover the sub survey area from one side to the other in a direction between 70° and 90° from the ordinary survey direction.

8.4 *Survey area and line planning*

The total survey area shall be split into sub-areas (blocks), where data from each of which is considered a sub-delivery. Division of the blocks has particular implications for backscatter data as it is this dataset which is most sensitive to changes in acquisition settings which typically need to be changed with depth (gain, pulse length, frequency).

The following points should be followed as far as practically possible during survey planning:

- Blocks should be as large as is practically possible (typically in the range 500-2000 km^2)
- Blocks need not have a regular geometry, but will rather follow depth contours allowing consistent acquisition settings and a single MBES and vessel to be used within each block.

8.5 *Reports*

All reports shall be sent by e-mail to a mailing list provided by the Client.

Daily reports during survey

These are very brief reports indicating daily problems and progress.

Weekly reports during survey

More comprehensive (but still brief) reports indicating survey progress and status related to schedule.

The report shall contain

- The estimated survey completion date
- The surveyed area [km^2] and a plot showing the area.
- Processing and QC progress and status related to schedule
- The estimated final delivery date

Weekly processing reports after survey

Brief reports indicating processing and QC progress and status related to schedule. The report shall include the estimated completion date. Processing reports are requested during the time from survey completion until the data are accepted.

Final report

A final survey report shall be delivered as a part of the documentation. This report is the Contractors summary of the survey, and shall contain documentation of all hydrographical data, data processing, interpretation and information of data quality.

The report shall as a minimum contain:

- Data collection method and their technical specifications and comments on the processes
- Geodetic reference system, positioning-methods and their error budgets
- Date and time for the data collection
- All corrections applied to the data and details of Quality Control Procedures

- Estimates of random and systematic errors concerning the data
- Other data referred to in IHO S44, Chapter 5
- Experiences, comments and findings

Processing parameters should be included digitally together with the project data, or be included in the final survey report.

The final survey report shall be submitted to the Client no later than three weeks after the completion of the quality controlled data set.

Executive summary report
Following all data deliverables, an executive summary report shall be delivered. A template for an Executive Summary Report can be found in *Info_A_Executive Summary_template.doc*

9 Bathymetric data processing

Careful processing is required to obtain the specified data quality.

The processing shall focus on removing all faulty soundings at the same time as the seabed feature information is preserved.

Artefacts in the processed XYZ- data shall be kept at an insignificant level not disturbing the seabed image.

Faulty soundings shall be flagged as rejected, and no soundings shall be deleted.

XYZ-data shall not be smoothed.

10 Data product delivery

All data related to a survey block shall be delivered, including data outside the block limit.

Data types:

- Accepted bathymetry XYZ-data (observed data)
- Rejected bathymetry XYZ-data (observed data)
- Horizontal and vertical uncertainty for each depth value (THU and TVU)
- Survey area limits generated from accepted data
- Preliminary bathymetry grids based on roughly processed data and referred to the MSL shall be delivered upon request.
- Preliminary backscatter mosaics (floating point geotiff)
- Sensor data
    - MBES (depths, backscatter, water column)
    - Sub-bottom profiler
    - Motion sensor
    - GNSS data (RINEX)
    - SVP

Data units and resolution:

- Depths shall be given in metric units with 0.01 m resolution.
- Positions shall be given as decimal degrees with 0.0000001° resolution.
- THU and TVU shall be given in metric units with 0.01 m resolution.
- Grids shall be metric in the UTM projection. The Contractor shall include information about the utilized gridding algorithm and the parameter settings. The grid cell size is depth dependent.

Depth region	Grid cell size
0-500m	5m
500-1200m	10m

Data format:

XYZ-files:

XYZ- data may be divided into geographical (not projected) sub-areas. A file shall contain all accepted XYZ-data within the sub-area. The files (both Rejected and Accepted XYZ-data) shall be ASCII data and use the following record format:

Latitude longitude depth THU TVU

Example:

```
71.5047873 16.4877026 278.3 1.2 0.7
71.5047728 16.4876353 277.6 1.3 0.6
```

Backscatter mosaics:

Backscatter mosaics produced as QC for each survey block (section 7.7) are a required deliverable. These data shall be delivered as georeferenced floating point *.tif* raster files unless otherwise agreed between the Conractor and the Client.

Sub-bottom profiler:

Data should be delivered in SegY-format with UTM coordinate system.

Sensor data:

Sensor data shall be delivered in a format agreed between the Contractor and the Client. The Client shall have access to all data collected during the survey.

Survey area limits:

The Survey area limit shall have the file extension *.irap*. This is a geographical ASCII IRAP format without header.

Example:

```
16.4877026 71.5047873 0.0
16.4876353 71.5047728 0.0
16.4875556 71.5047557 0.0
999.00 999.00 999.00
16.4871803 71.5048135 0.0
```

```
16.4871171 71.5048003 0.0
16.4873026 71.5048173 0.0
999.00 999.00 999.00
```

Exchange medium and format

The Contractor shall deliver all digital data on External-HDD, DVD or CD-ROM when suitable. All data shall be submitted in ASCII-format if not otherwise agreed between the parties. Checksum (sha1sum) for all individual files shall be generated prior to copying the files to dispatch disk. File checksums shall be a part of the delivery.

If available, the delivery shall include HIPS HDCS data and csar files.

File and folder structure of delivery (including naming convention):

By first delivery XYZ files and survey limit files shall have a revision number rev0 in the filename. If first delivery is rejected, later deliveries of the same survey should be named revA, revB, etc.

Mareano/ S**urvey name**/

- Survey report
- Backscatter mosaics
- Survey limits

Mareano/ **Survey name/ XYZ/Accepted_points/**

Mareano/ **Survey name/ XYZ/Rejected_points/**

Mareano/ **Survey name/ XYZ/Gridnodes/**

Mareano/ **Survey name/ RAW/** (sensor data except WCD)

Mareano/ **Survey name/RINEX/**

Mareano/WCD/

Water column data should be placed in a top level folder

11 Metadata

The metadata shall contain all significant information related to the Hydrographic data and the data processing. The metadata shall be included in the Executive Summary Report. The time for start and end of the survey and a vessel configuration file shall be included.

12 Data storage

Contractor shall store all collected Hydrographic data for at least 5 years.

13 Support

The Contractor shall provide support regarding the survey and the deliveries for at least 2 years after data acceptance.

14 Operation manual

The Contractor shall provide an Operation Manual (OM), which shall contain a complete description of the survey and the processing work. The description shall as a minimum include a description of the total survey spread, calibration, verification, data acquisition, data processing and data delivery

procedures. In the OM, the Contractor should give a feedback on his ability to fulfil every individual requirement of this technical specification.

15 References

Chen and Millero	*Algorithms for computation of fundamental properties of seawater*, Unesco technical papers in marine science 44, page 46.
Del Grosso	*New equation for the speed of sound in natural waters.* *V.A. Del Grosso. J. of Acoustical Soc. of America oct 1974 p1064*
Francois and Garrison	*Francois R. E., Garrison G. R., "Sound absorption based on ocean measurements: Part II:Boric acid contribution and equation for total absorption*", Journal of the Acoustical Society of America, 72(6), 1879-1890, 1982,
IHO S-44	*International Hydrographic Organization Standard for Hydrographic Surveys, Special publication No 44. 5th edition, February 2008.*
Lurton, X.; Lamarche, G. (Eds)	*Backscatter measurements by seafloor-mapping sonars. Guidelines and Recommendations. 2015. 200p. http://geohab.org/wp-content/uploads/2014/05/BSWG-REPORT-MAY2015.pdf*